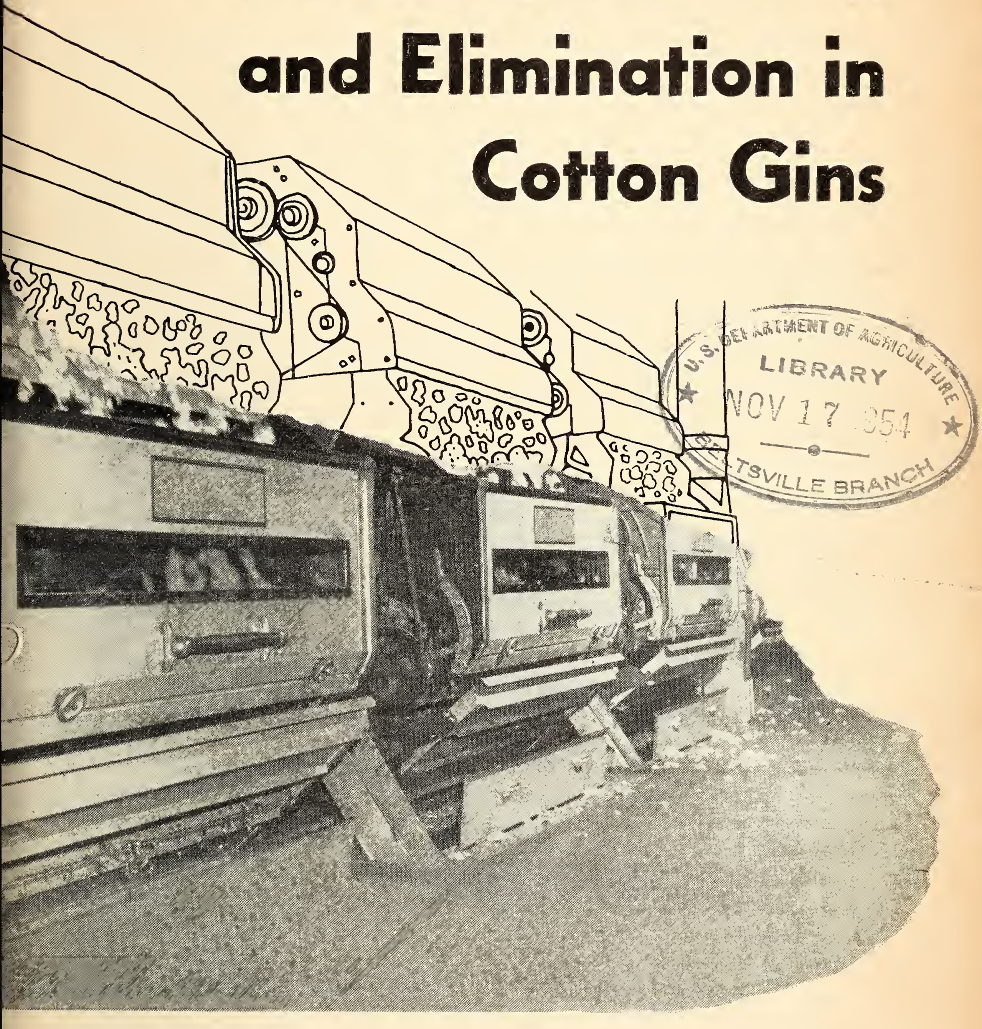
Effects of Electrical Bonding and Grounding on Static Generation and Elimination in Cotton Gins



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Effects of Electrical Bonding and Grounding on Static Generation and Elimination in Cotton Gins

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PURPOSE AND SCOPE

Static electricity presents a serious problem to cotton ginners, especially in the arid cotton regions of the southwestern United States. Frequently, enough static builds up on the cotton in a gin to cause it to adhere to machinery parts, resulting in chokage that reduces the gin's output. In extreme cases static may cause a complete shutdown of the gin.

Electrical grounding of machinery has long been advocated as a way to eliminate static at cotton gins. In the past the United States Department of Agriculture has issued several publications recommending the grounding of gin machinery to prevent fires caused by static and to eliminate static in cotton gins.[2] The investigations on which those publications were based were made during and soon after World War I. Since that time revolutionary changes have occurred in cotton-ginning machinery, processes, and areas of production. For these reasons additional investigations were considered desirable, especially in the Southwest where static often interferes greatly with ginning operations.

This circular deals with bonding and grounding as affecting the accumulation of static on cotton during ginning, and it is the result of investigations made at the United States Cotton Ginning Research Branch Laboratory at Mesilla Park, N. Mex., from 1950 to 1952, inclusive. The term "bonding," as used herein, means providing electrical connections between all metal parts of the gin. The value of grounding as protection against lightning and short circuits in electrical equipment is not questioned; and in this connection, it is recommended that all cotton-gin installations conform to the standards of the National Electric Code and to local and State regulations.

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[1] This circular deals with certain engineering phases of work on cotton ginning jointly conducted by the Agricultural Engineering Research Branch, Agricultural Research Service, and the Standards and Testing Branch, Agricultural Marketing Service.

[2] BROWN, H. H. COTTON GIN FIRES CAUSED BY STATIC ELECTRICITY. U. S. Dept. Agr. Dept. Cir. 28, 7 pp., illus. 1919.

ROETHE, H. E. GROUNDING COTTON GINS TO PREVENT FIRES. U. S. Dept. Agr. Dept. Cir. 271, 4 pp., illus. 1923.

ROETHE, H. E. FIRES IN COTTON GINS AND HOW TO PREVENT THEM. U. S. Dept. Agr. Cir. 76, 8 pp., illus. 1929.

STATIC PHENOMENA

Static electricity, or "static" as it is generally called in the cotton ginning industry, is electricity that has been generated on, or transferred to, a material and remains there temporarily. Sooner or later the static or stationary electric charge leaves, and the material resumes a neutral condition. The rate of discharge depends upon the type of material, the conditions of the material, and its surroundings. When two dry, dissimilar materials, such as cotton and galvanized sheet iron, are rubbed together or contacted and then separated, the materials generally become charged with static electricity. One material becomes positively charged, and the other becomes negatively charged.

Charged materials exhibit certain characteristics that are explained by three fundamental laws of electricity. These laws are: There are two kinds of polarities of electric charges, positive and negative; electric charges of the same polarities repel one another, while charges of opposite polarities attract one another; and the force of attraction or repulsion between any two charges is directly proportional to the product of the amounts of the charges, and inversely proportional to the square of the distance between them. When the amounts of static charge on the materials become sufficiently large, problems arise because of the forces of attraction and repulsion, the heat energy, and the possible physiological shock resulting from static discharges.

The generation of static on cotton in sufficient quantities to be troublesome to the ginner requires two conditions: A combination of the variable of electrical conductivity, moisture content, and temperature, as well as any other factors conducive to static generation; and an action to cause generation of static. The movement of cotton through the piping and ginning machinery supplies sufficient action to cause generation of the electrical charge, provided the first condition is present.

When a charged mass of cotton is brought near a neutral mass, such as the metal wall of cotton piping or machinery, a charge of the same quantity but of opposite polarity is induced [3] on the other mass. The charge induced on the metal wall may be regarded as a mirrored image [4] of the charge on the cotton. Since the charge on the cotton is of one polarity and the induced, or imaged, charge on the metal is of the opposite polarity, the cotton is attracted to the metal. The closer the cotton comes to the surface of the metal, the greater is the force of attraction. The action resembles that of a magnet held near a piece of iron; the nearer the magnet is to the iron, the greater the pull or attraction between them.

One important fact is that electrical grounding of the metal surfaces has little or no effect on the attraction between electrostatic charges of opposite polarity in the cotton in a gin. Whether the metal surface is grounded or ungrounded, the electrostatically charged cotton tends to stick to the metal surface because of the induced opposite charge. Grounding the metal will not eliminate the induced charge, but some reduction in the charge may occur through the grounding of the small

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[3] LOEB, L. B. FUNDAMENTALS OF ELECTRICITY AND MAGNETISM. Ed. 3, 669 pp., illus., ch. 13, 170–171. New York and London. 1947.

[4] GILBERT, N. E. ELECTRICITY AND MAGNETISM. 585 pp., illus., ch. 6. New York. 1941 (reprint).

fraction of cotton fibers making direct contact with the metal. If all the cotton-fiber area could be grounded, the static charge would be eliminated from the cotton. However, when the electrical conductivity is low enough for large amounts of static to be generated on the cotton by ordinary processing, this same low conductivity prevents the static charges from flowing from the fibers to the grounded metal structure except in areas that make direct contact with the metal; and these areas comprise only a minute percentage of the total charged surface area.

Thus far, the only situation considered has been that of a charged mass of cotton brought near a neutral mass. There are two other possible situations: When the other mass, such as the metal wall, is charged with an electric charge opposite in polarity to that in the cotton; and when the mass is charged with an electric charge of the same polarity. In the first instance, the attraction between the cotton and the charged wall would be greater than if the wall were neutral, because the induced charge on the wall—caused by the presence of the charge on the cotton—would be additional to the charge on the metal itself, so that the total attractive force between the cotton and the wall would be proportional to the sum of the two charges. In the second instance, however, the independent charge on the wall would be of the same polarity as that in the cotton, and it would therefore tend to repel the cotton. The total force between the cotton and the wall would be the difference between the attractive force caused by the induced charge and the force of repulsion caused by the charge added to the wall. If the wall was electrically grounded, these two situations could not exist, since the wall would be neutral. These last two situations are not likely to occur in modern metal cotton gins.

TEST PROCEDURES

Before the equipment was bonded and grounded, electrical-resistance measurements were taken [5] to determine the intrinsic resistances between the handling, drying, cleaning, and ginning equipment installed in the laboratory and ground. In taking the measurements, it was found that the ginning equipment was grounded through the frame of a triple-ram cotton press extending below the water table where the laboratory building is located. To further insure a good electrical ground, this frame was connected to the laboratory cold-water lines with braided, tinned-copper, A. W. G. No. 7 cable.

The taking of resistance measurements and the installing of the bonding and grounding were done in two parts. The first part consisted of the bonding of the stationary equipment followed by taking the electrical measurements thereon. The second part was the bonding of the rotating parts of the equipment, such as cleaner drums and shafts, screw conveyors, and saw shafts, and the taking of electrical measurements on these.

Many ginning tests were made in which the bonded and grounded equipment were used, and observations and measurements of the static on the cotton being processed were made to evaluate the usefulness of the grounding installation.

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[5] All electrical-resistance measurements were taken with a portable Wheatstone resistance bridge.

BONDING AND GROUNDING INSTALLATION

Stationary Parts of the Equipment

As previously stated, the resistance measurements taken before any bonding and grounding cables were installed (table 1) showed that good electrical paths already existed between the ground and the stationary equipment. The largest single measured resistance was only 0.005 ohm, and the average was 0.003 ohm. The average deviation was ±0.001 ohm. Some measurements were repeated with and without the gin machinery in operation to determine the effects of motion on the resistances, but no variations were found.

TABLE 1.—*Electrical resistances measured between the lettered locations on the stationary cotton ginning equipment used in the static study (1951–52 season) and the reference ground (east support column of press)*

Measured from the reference ground to [1]—	Electrical resistance, and when measured with reference to installation of bonding—			
	Before	Immediately after	4 months later (preceding 1951–52 ginning-season tests)	9 months later (preceding late-season, static-study tests)
	Ohm	*Ohm*	*Ohm*	*Ohm*
Overflow (A)	0.004	0.003	0.002	0.001
Pipe to tower (B)	.004	.003	.004	.002
Separator (C)	.004	.003	.003	.002
Tower outlet (D)	.003	.002	.003	.002
Pipe from tower (E)	.004	.002	.004	.002
Pipe from tower (F)	.005	.002	.004	.002
Pipe from tower (G)	.004	.002	.004	.002
Separator (H)	.005	.003	.004	.002
Rear of gin (I)	.002	.002	.002	.002
Lint flue (J)	.001	.002	.002	.002
Lint flue (K)	.001	.003	.002	.002
Condenser (L)	.001	.003	.002	.002
Lint slide (M)	.001	.002	.003	.002

[1] Letters refer to locations shown on figure 1.

The bonding installed on the machinery consisted of continuous lengths of braided copper cable, size A. W. G. No. 10, fastened along two opposite sides of each machine. Short pigtails connected cover plates and other stationary metal parts to the continuous lengths. Each point of contact between a cable and the metal being bonded was carefully cleaned of paint and other foreign matter, and the cable was securely bolted on. All connections between different pieces of bonding cable were bolted and soldered to insure low resistance. All the piping that carried cotton was bonded, and the equipment used for a simple ginning setup was bonded. The setup used consisted of the suction piping, a separator and Government-type tower drier, a second separator and a 7-cylinder cleaner, screw conveyor distributor, extractor feeder, gin stand, condenser and lint cleaner, lint flue and condenser, and lint slide (fig. 1).

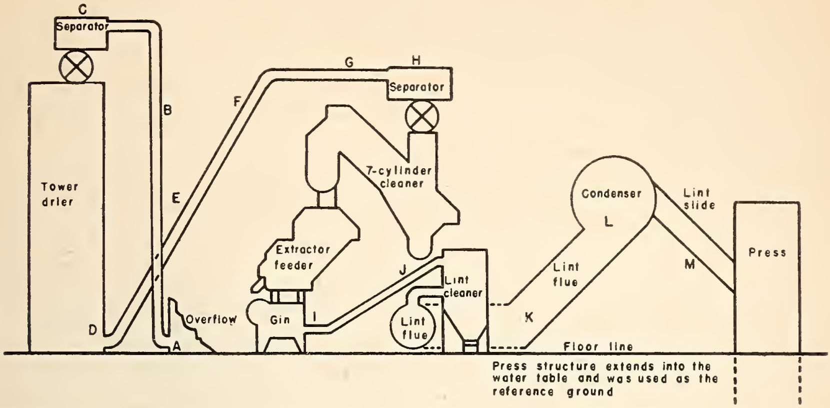

FIGURE 1.—Ginning equipment used for studying the effects of bonding and grounding. Letters indicate locations where electrical resistances were measured on the stationary equipment (see table 1). All the equipment shown was electrically bonded together with braided copper cable consisting of 384 No. 36 wires and having a cross-sectional area of 9,600 circular mils. This cable was bonded to the terminals by A. W. G. No. 10 copper wire.

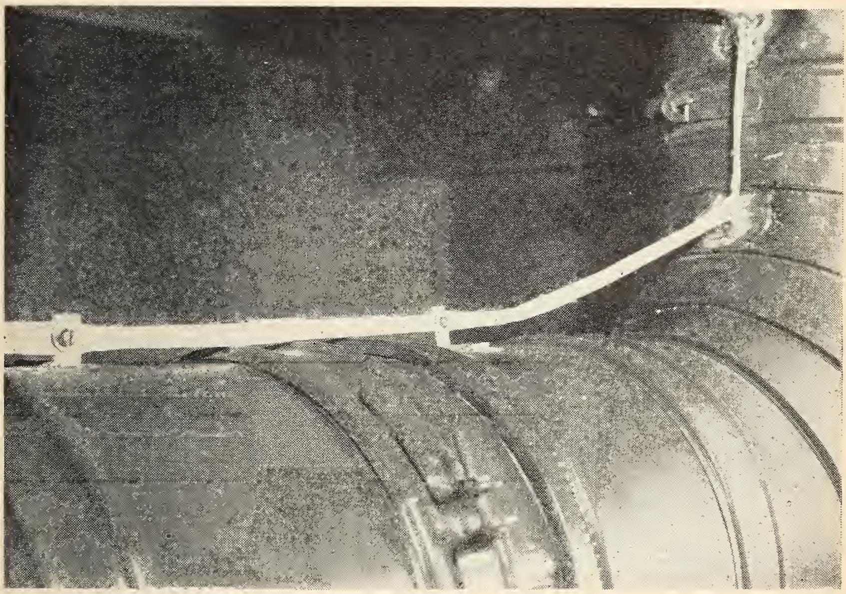

FIGURE 2.—Electrical bonding cable attached to metal brackets welded to cotton-conveying metal piping.

Small metal brackets were made from 24-gage sheet iron; these were brazed to each section of pipe (fig. 2) and to other parts to be bonded on which there were no convenient points of attachment.

The cable was then bolted to these brackets. A main ground cable, A. W. G. No. 7, was connected from the press frame along one side of the gin to the main waterline and then back along the other side of the gin returning to the press. All the bonding cables were connected to the main ground cable through multiple-contact connector plugs (*Jones*, series 300, 8-contact).[6]

Immediately after the completion of the bonding and grounding of all the stationary equipment, another set of resistance measurements was taken. The resistances were approximately the same as before bonding and grounding, but the variations between individual resistances and the average resistance were smaller. The resistances between points chosen throughout the ginning setup and the reference ground are listed. The resistances between many other points and ground were measured, but only the ones listed were remeasured. Two additional sets of measurements were made during the study and are given. (See table 1.)

Comparison of the resistance before and after bonding shows that bonding merely aided in reducing variations between resistances. The ideal experimental setup would have consisted of a similar layout, but with each individual piece of equipment electrically isolated from all others and ungrounded before bonding was installed. Another important fact is that the measured resistances were so small that, for all practical purposes, any one of the resistances could be called a dead short.

Moving Parts of the Equipment

The moving parts that were bonded consisted of all the rotating shafts of the machinery included in the setup shown in figure 1. These shafts were bonded, and provisions were made for connecting the bond cables to ground when desired. The satisfactory bonding of these shafts presented a much greater problem than did the bonding of the stationary equipment. The electrical resistance between a metal shaft at rest and the bearing housing, if measured, is usually found to be low—probably a fraction of 1 ohm. However, as the shaft rotates, the electrical resistance is apt to increase, because an insulating film of lubricant is generally formed between adjacent moving and stationary parts.

Two possible methods of effectively grounding a moving shaft are: To use an electricity-conducting bearing lubricant; or to make contact between the moving shaft and some type of stationary brush. A limited investigation was made of conducting bearing lubricants, but as consistent resistances below 1 ohm were not obtained, this method was discarded. Spring-loaded brushes of solid copper were used to make contact with the shafts or with steel sliprings fastened to the shafts. Brushes of this type were chosen after comparative tests were made using flat steel springs, ignition-type contacts, brushes composed of varying mixtures of copper and graphite, and solid cop-

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[6] The mention of a trade product does not imply its endorsement by the U. S Department of Agriculture over similar products not named.

per brushes. As copper brushes of the size desired were not obtainable commercially, they were fabricated in the laboratory shop. The brush holders were of insulating material, mounted in brackets fabricated to fit each shaft. In many instances the shafts were not exposed for a sufficient length for a brush contact to be made, or a shaft contained a keyway; steel sliprings were therefore made and fastened to the shafts, and the stationary brushes made contact with these rings (fig. 3).

The brushes were electrically connected together in convenient groups with braided copper bonding cable. A few brushes were grounded to the nearest stationary metal structure with short cables, but most bonding cables terminated in a connector plug similar to those used on the stationary bonding cables.

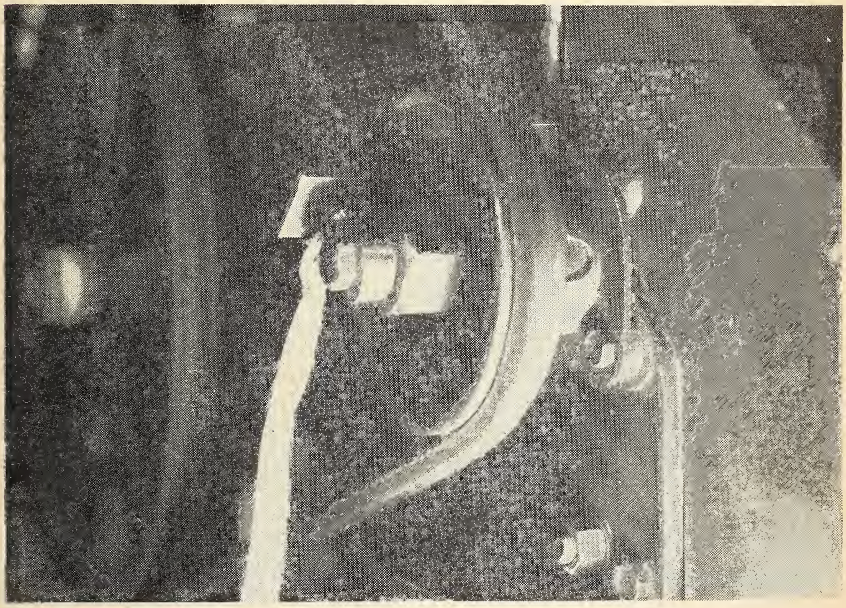

FIGURE 3.—Spring-loaded copper-brush holder in bracket with bonding cable attached for grounding a rotating shaft. The brush is making contact with the moving shaft through the steel slipring bolted to the end of the shaft.

The locations of some of the shafts that were bonded are shown by numbers (fig. 4). A total of 44 shafts were bonded, using copper brushes. Tabulated resistances for 31 of the brush-to-shaft contacts are given (table 2). Resistances between the rotating shafts and the bearing housings before the brushes were installed are not given. These were never accurately measured, as belt static and other sources of potential across these points made the use of the bridge-type resistance-measuring instrument unsatisfactory.

All these measurements were made with the machinery operating at full speed because the resistance became extremely small when the machinery was at rest. All brush-to-shaft resistances were below 1 ohm immediately after the installation was completed. (See table 2.) After the machinery had been operated for some time, some of the resistances rose to as high as 5 ohms (S–14 to No. 12), while others remained low. Brush wear, vibration, accumulation of foreign material on the contact areas, and slight eccentricity of some sliprings contributed to changes in resistances. Twice during the 1951–52 ginning season, all brush and shaft contact areas were cleaned with carbon tetrachloride. Once during the latter part of the season, just prior to the second series of static ginning tests, all brushes were examined and all showing excessive wear were replaced.

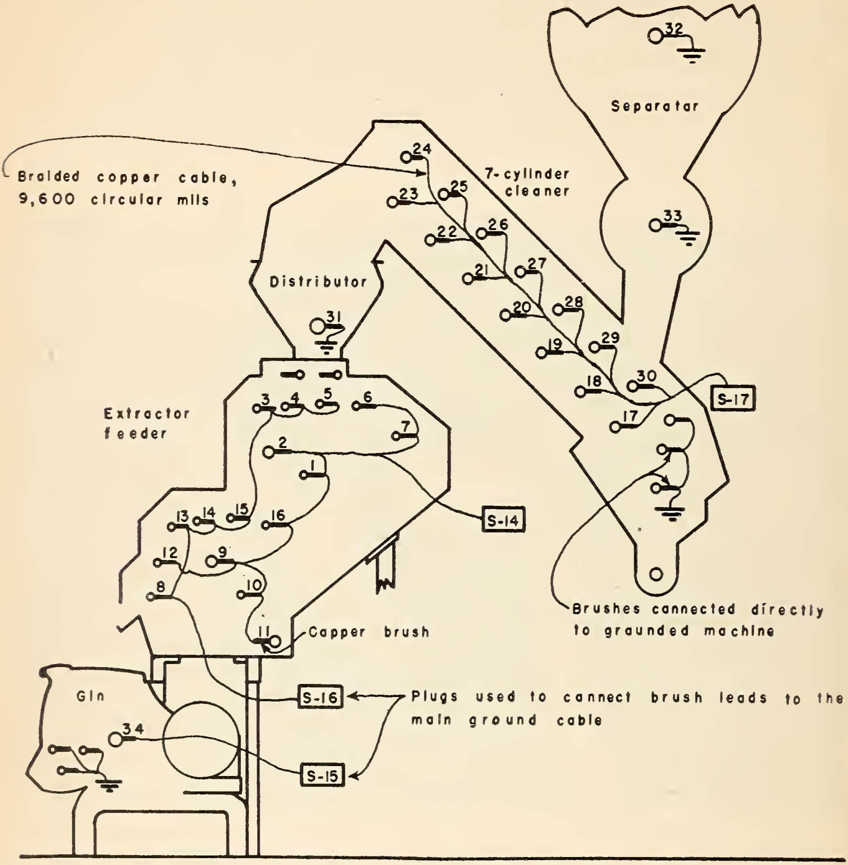

Figure 4.—Part of the electrical bonding system used on the rotating shafts of the ginning equipment of figure 1. End view of separator, 7-cylinder cleaner, screw-conveyor distributor, extractor feeder, and gin stand, showing relative shaft positions and positions of copper bonding brushes. All brushes are similar. The copper cable leads from the brushes terminate at the indicated plugs that connect to the main ground line, except those shown connected directly to the grounded stationary metal structures.

TABLE 2.—*Electrical resistance measured between bonding plugs and rotating shafts on the cotton-ginning equipment used in bonding and grounding study (1951–52 season). For grounding, all plugs were connected to the main ground cable that was connected to the main ground point (east support column of press). All measurements were made while all machinery was operating.*[1]

Electrical resistance measured—				
Between plugs and shafts		Immediately after brushes were installed	After brushes had been installed 4 months	After brushes had been installed 10 months; all ginning completed
Plug	Shaft [2]			
No.	*No.*	*Ohm*	*Ohms*	*Ohms*
S–14	1	0.03	0.5	4.2
	2	.4	.4	4.0
	6	.09	.3	.06
	7	.03	.3	.1
	9	.5	1.7	1.5
	10	.4	3.7	3.5
	11	.2	2.5	.8
	12	.6	5.2	3.0
	16	.1	1.2	2.2
S–15	34	.02	.1	.1
S–16	3	.03	.1	.1
	4	.03	.6	3.5
	5	.04	.3	.1
	8	.1	.2	.1
	13	.7	.2	.1
	14	.04	.1	.4
	15	.1	.3	.3
S–17	17	.1	.2	.5
	18	.1	.9	.1
	19	.2	.7	.2
	20	.1	.3	.2
	21	.2	.1	.3
	22	.1	.5	.8
	23	.1	.2	.1
	24	.3	.9	.4
	25	.2	.1	1.5
	26	.5	.2	1.3
	27	.1	.2	.8
	28	.3	.1	.3
	29	.3	.6	.4
	30	.2	1.2	.1

[1] The resistance drops to a value close to zero when the machinery is at rest.
[2] Shaft speeds range between 100 and 1,000 r. p. m.

PERFORMANCE TESTS

General Tests

The bonding and grounding system was completed approximately 4 months before the equipment was used for ginning. Another set of resistance measurements was taken immediately before start of the annual ginning work performed at the laboratory. Thirteen resistances were chosen in the stationary equipment and remeasured, and 31 shaft-to-bond cable resistances were remeasured. (See table 1, column 4, and table 2, column 4.)

The bonded and grounded laboratory ginning equipment was used intermittently from late September 1951 through the first week of February 1952. During this period, except for the two special tests below, all bonding cables were connected to the main ground cable. This insured the electrical grounding of all the equipment except the moving shafts on certain seed-cotton cleaning equipment not included in the setup of figure 1 but used in some of the tests.

Observations of the static intensities were made on all cotton processed during the 1951–52 season at the Mesilla Park Laboratory. These included observations of visual indications of static, as well as rough measurements of the relative amounts of static on cotton obtained by using simple goldleaf electroscopes. Quantitative measurements were also made with a vacuum-tube voltmeter (input resistance of 1.1×10^9 ohms).

The equipment, from the screw-conveyor distributor to the press, was used on all tests and was well grounded; yet at times during the season there was enough static on the seed cotton[7] coming from the extractor feeder to cause it to adhere to the grounded metal feeder apron. Also, the lint[7] emerging from the condenser over the lint slide frequently contained enough static to prevent the lint from leaving the doffer roll. Consequently, the lint wrapped around this roll and caused chokage instead of dropping onto the lint slide, except when other means of eliminating or reducing the static on the lint was used at this location. At times, when the charged lint dropped to the grounded lint slide, it stuck there and had to be manually pushed into the press box.

Special Tests

Two special series of ginning tests were also performed to determine the effects of the bonding and grounding system. The same variety of cotton (Acala 1517) was used for both series. The cotton used for the first series was midseason while that used for the second series was late-season; both were handpicked. Each series consisted of a control lot and a test lot, and 3 replications were made, or a total of 6 ginning lots per series. All the lots were processed through the equipment setup of figure 1. The control lot was run with all bonding-cable plugs disconnected. All plugs were then connected to the main ground line, and the second lot was run.

During the processing of each lot, the static charge on the cotton was measured at four points in the ginning system. As these measurements were taken with different types of instruments and in different manners, comparison of data from different points can only be made qualitatively. This has been done to give an overall picture of the static on the cotton during processing through the setup. The relative static

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[7] The term "seed cotton" means raw cotton fiber still attached to its seeds, and is synonymous with the term "cotton," while the term "lint" refers to the ginned fiber.

charge on the seed cotton emerging from the bottom of the tower drier was measured with a vacuum-tube voltmeter, using an insulated metal probe inserted into the outlet pipe. Some of the seed cotton passing through the pipe made contact with this probe, and the potential difference between the probe and ground was read from the voltmeter. At the feeder apron and lint condenser, the static on the cotton was measured by using a goldleaf electroscope. The divergence of the goldleaf is an indication of the amount of static charge imparted to the electroscope from contacting the charged cotton.

Results of Tests

The relative amounts of static were measured on the cotton at four locations during ginning (table 3). A comparison of the lots ginned with equipment not grounded and those lots ginned with all equipment grounded showed no change in the intensities either in midseason or in late-season cottons.

TABLE 3.—*Relative electrostatic charge intensities on seed cotton and lint in the ginning system. An arbitrary scale is used*[1]

Cotton and replication	Equipment setup	Relative static level at—			
		Tower outlet	Feeder apron	Inlet to lint cleaner	Condenser outlet and lint slide
Midseason crop:					
Replication 1	Not grounded	3–4	2	2–3	4–5
Replication 2	do	2	2	1	4–5
Replication 3	do	1	2	2	4
Replication 1	Grounded	3–4	2	2–3	4–5
Replication 2	do	2	2–3	2	5
Replication 3	do	1	2	2	4
Late-season crop:					
Replication 1	Not grounded	2	2	3	4
Replication 2	do	2	2	3	4½
Replication 3	do	2	2	3	4
Replication 1	Grounded	2	2	3	4
Replication 2	do	2–3	2	3	4½
Replication 3	do	2	2	3	4

[1] Relative scale: 0, no detectable static; 1, measurable static; 2, light static; 3, medium static; 4, heavy static; 5, extremely heavy static.

The conclusion from the data obtained from both the special and the regular ginning tests is that static electricity is always generated on cotton when conditions are favorable, even though the cotton is processed through bonded and grounded ginning machinery. Bonding and grounding do not prevent such ginning trouble as chokage caused by the charged cotton sticking to the piping or machinery.

MISCELLANEOUS EXPERIMENTS

A small, variable-speed, single, rotating, spike-drum unit was built for use in studying static generation on small samples of cotton (fig. 5). The spike drum (c) rotated adjacent to a stationary metal section (b). The spike drum and the stationary section were insulated by dry wood from each other and from all other metallic parts of the unit. Weighed samples of cotton introduced into the chute (a) passed over the stationary section and into the insulated container (d).

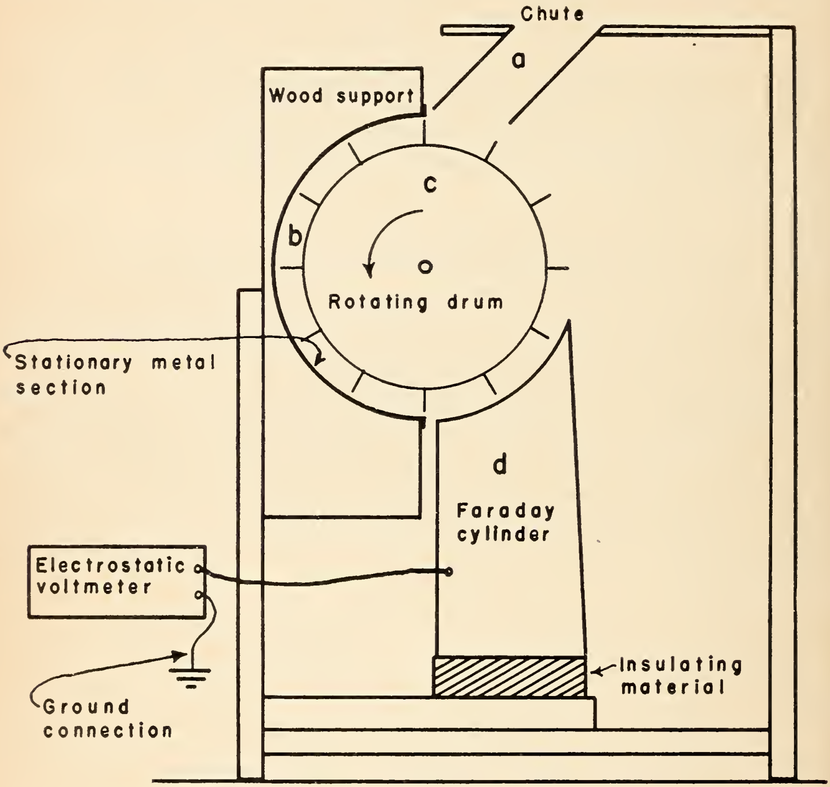

Figure 5.—Basic parts of the variable-speed, spike-drum unit used to study electrostatic-charge generation on small samples of cotton.

This container acted as a "Faraday cylinder,"[8] also called a Faraday pail or bucket. The static charge on the cotton was measured by an electrostatic voltmeter connected between the container and ground. It was possible to ground or unground the cylinder, the stationary section, or both.

Numerous tests were run using 50-gram samples of seed cotton, to determine whether there was a difference in the quantity of static

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[8] Keggin, J. F., Morris, G., and Yuill, A. M. STATIC ELECTRIFICATION IN THE PROCESSING OF FIBRES: VARIATION WITH MOISTURE REGAIN DURING CARDING. Textile Inst. Jour. 40: T702–T714, illus. 1949.

charge generated on the cotton when the cylinder and stationary section were grounded and not grounded, provided all other conditions—such as air temperature, relative humidity, and cotton moisture content—were kept the same. As no difference was found, it was concluded that the electrostatic-charge generation on the cotton was independent of the electrical bonding and grounding.

SUMMARY AND CONCLUSIONS

Static electricity causes considerable trouble in ginning, especially in the Southwest where the relative humidity of the air normally is low during the ginning season. Since grounding has previously been advocated to eliminate the trouble, experiments were conducted at the United States Cotton Ginning Research Branch Laboratory at Mesilla Park, N. Mex., from 1950 to 1952, inclusive, to determine the effectiveness of this method.

In conducting these experiments it was found that the ginning machinery in the laboratory was already well grounded. Consequently, the addition of a bonding and grounding system of wires did not materially change the electrical resistance except for those moving parts that were insulated before bonding by lubricants in the bearings.

The experiments showed that static was generated on cotton being processed, and that ginning troubles occasioned by static were encountered despite thorough grounding of machinery. These findings are explained by assuming that the charged cotton was not grounded through the machinery because of the low conductivity of cotton fibers under the conditions conducive to the generation of static, and also because of the minute number of fibers making direct contact with the metal.

The results of these experiments led to the conclusion that bonding and grounding do not solve the problem of static in cotton ginning and the resultant clogging that reduces the output of the gin.

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